What do science teachers think biotechnology is? Does it matter?

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Abstract

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Full Text

Headnote

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What is biotechnology? What do science teachers think biotechnology is? Does it matter? We argue that a vital task of the science education community is to fully prepare our students to be 'technological citizens'. This means we need to be clear about what is this thing called biotechnology, a cutting edge science and technology with profound impact on all our lives. We summarise the views of science teachers, and then suggest how science teachers might tackle the important question of what biotechnology is.

WHAT IS BIOTECHNOLOGY?

There appear to be two broadly distinct uses of the term 'biotechnology'. One refers to a long tradition of modifying the characteristics of various life-forms to make them more useful to humans. In this view, modem biotechnologies are a continuation of practices going back to the Babylonians, and do not represent a radical break with the 'past'. The food industry is the oldest and largest user of these biotechnological processes, which include traditional areas such as cheese making, fermenting and brewing to produce alcoholic drinks and bread making. The other view, represented particularly by anti-biotechnology activists such as Rifkin (1991) is that biotechnology is a radically new field in which molecular biology has given humans unprecedented powers of genetic manipulation. Biotechnology allows us to modify nature; this capacity needs to be exercised cautiously (Schibeci, 2000, p. 28).

Does it matter which view we subscribe to? Is this just semantics?

We believe it is important that science teachers develop informed views on what biotechnology is if they are to help their students develop similarly informed views. First, we present the views of a sample of Western Australian science teachers on What is biotechnology? We then suggest how science teachers, as a staff, can develop an informed view on this question.

WHAT DO WESTERN AUSTRALIAN SCIENCE TEACHERS THINK?

A survey was developed that comprised four sections: personal information, understanding of biotechnology, barriers to teaching biotechnology and factors that would encourage the teaching of biotechnology. Here, we report the results on science teachers' understanding of biotechnology. Background information on teacher qualifications, years of experience, main teaching area and professional development in biotechnology from the first part of the survey was sought to compare data according to teachers' experience and teaching area knowledge. This is the subject of another paper. In this paper, the focus is what science teachers think biotechnology is.

What is Your Understanding of Biotechnology?

The survey was written using information gleaned from media articles collected over several months from the West Australian newspaper, Time magazine, local television news items and popular women's magazines. Twenty-three items were selected for inclusion (see Box 1). They were not arranged in any particular order on the survey sheet, although some related items were juxtaposed. Teachers were asked to indicate which items they thought were included in biotechnology: Yes/No/Don't Know.

The surveys were sent to the Heads of Science Departments, through the Principal, in 33 WA Department of Education senior high schools. The Heads of Science Departments were asked to administer the survey to all of the science teachers in the school. As an incentive to complete and return the surveys, a package of support materials was offered on receipt of the surveys from the school.

About 180 science teachers were targeted in the 33 schools. Not all teachers completed a survey, as there was a provision in the instructions for voluntary participation; 105 returns were received. Some returns were late and some were lacking important details, and so were not included in the data analysis. The sample population was 88 teachers from 19 different schools. This represents a 58% response rate. Of the 88 teachers in the sample, 44 had more than 15 years experience; 43 had a biological science background.

Results (Table 1 &Table 2)

The 'Yes' responses were used as 'included in biotechnology' whereas the 'No' and 'Don't know' were combined as 'not included in biotechnology'.

All items in the list were included in biotechnology by 18.2% of respondents.

What understandings of biotechnology do science teachers have? Our pilot project sheds some light on this question. Teachers' understanding seemed to fall into one of four major categories:

Table 1: Items *included* in biotechnology by teachers (n=88)

Rank	Item	Percentage
1	4. producing synthetic growth hormones	95
2	13. cloning	94
3	17. transferring a gene from one organism to another	93
4	3. screening for genetic diseases	92
5	8. developing vaccines for new influenza viruses	92

Rank: The most frequently nominated items (in order) included in 'biotechnology'
Percentage: The percentage of the sample who nominated the item be included in 'biotechnology'

Table 2: Items *not included* in 'biotechnology' by teachers (n=88)

Rank	Item	Percentage
1	16. collecting information on numbers of cancer patients in WA	69
2	22. use of surveys to find links between lifestyle and Alzheimer's disease	68
3	18. producing family trees showing the inheritance patterns of a gene	53
4	14. use of X-rays for medical diagnosis	50
5	15. experimenting to see the effects of tobacco on mice	48

Rank: The most frequently nominated items (in order) not included in 'biotechnology'
Percentage: The percentage of sample who nominated the item not to be included in 'biotechnology'

* include both old and new technology
* gene technology only
* techno-biology: technology applied to biology
* anything involving medical science.

Nearly half of the sample indicated that the use of X-rays was an example of biotechnology, but there is no use of organisms in this technology. This indicates the 'technobiology' view of biotechnology. The respondents who marked everything on the list as being included in biotechnology either didn't bother to read the items or saw something to do with genes, medicine and/or technology that fell into their view of biotechnology: anything involving medical science category.

Most teachers in our sample classified item 4: producing synthetic growth hormones as biotechnology. This would suggest that many teachers have some knowledge of this through various means. Several of the more recent biological textbooks have this as an example, along with the production of insulin, by genetically modified bacteria eg. Kinnear &Martin (2000, p. 400) and Taylor, Green, Stout &Soper (1998, p. 385).

A study of teachers in Hong Kong (Chan and Lui, 2002) revealed the following patterns. Teachers feel most confident in their understanding about the principle of fermentation, and most inadequate in their understanding about duplicating human organs on animal bodies, gene cloning and bioethics. The level of confidence, which is taken to show understanding of the basic principles of biotechnology, will have an effect on the pedagogical approach to the topic and so teachers would be more comfortable including the older forms of biotechnology

into their programs compared with aspects of gene technology. Also, teachers tend to accept those biotechnology applications that are beneficial to humanity, but are less accepting of animal duplication (cloning). Finally, teachers' inclination to include topics in the syllabus may be affected by positive attitude towards the topic, while teacher inclination to excluded topics more determined by limitation in knowledge rather than attitude. Topic choice is therefore a combination of attitude and knowledge. If teachers have a negative attitude and lack conceptual knowledge in biotechnology, then they will be less likely to engage their students in issues arising from biotechnology.

A study of biology teachers in Ireland (Michael, Grinyer and Turner, 1997) found teachers ambivalent. On one hand, they saw biotechnology was 'impure', because it was involved in the messy worlds of politics and ethics. On the other hand, it was 'pure' because it was part of 'the idealized realm in which useful scientific knowledge is produced' (p. 13).

Clearly, science teachers need opportunities to develop their own, informed views on what biotechnology is.

DOES IT MATTER?

Why is teachers' understanding of biotechnology important?

Teachers need to have a thorough grasp of the content of what they are teaching. Their knowledge should be sufficient to have an understanding of the underlying structure of their subject matter, and its relationship to other areas of knowledge. They should appreciate and be able to convey its complexify and richness.

(Schools Council 1990, cited in, Hatton, 1994, p. 37)

Teachers' knowledge of their subject is critical in shaping their curriculum and pedagogical decisions (Grossman, Wilson and Shulman, (1989) and Hashweh (1987) cited in Gabel, 1994, p. 14). Teachers' own knowledge of a subject will enhance or limit the opportunities a student has to learn the subject (McDiarmid, Ball and Anderson (1989) cited in Gabel, 1994, p. 14). Knowledgeable teachers will:

* be able to make sense of students' ideas, even when the correct terminology is not used
* recognise misconceptions and be able to change these
* draw on a background of suitable 'stories' to enhance engagement by students in learning in this conceptual area eg Dolly the sheep, cc the cat.

In developing informed views, teachers will be better placed to help their own students develop informed views. This is crucial if we are to help prepare students to be effective scientific and technological citizens.

'Science for citizenship'

The recent discussion paper, Young People, Schools and Innovation: towards an action plan for the school sector (http://www.dest.gov.au/schools/teachingreview/) is part of the national review of teaching and teacher education by the Commonwealth Department, DEST. It emphasises the importance of a culture of enterprise and innovation in schools. There is also the Interim Report: Attracting and retaining teachers of science, technology and mathematics that promotes the importance of links with academia for mentoring and student support in schools. These reports highlight the need for schools to prepare students for a culture of

innovation in science and technology. As a nation, we need not just develop brilliant ideas and inventions, but market them as well. Biotechnology has three characteristics that makes it an ideal vehicle for the school curricula. These are:
(1) Cutting edge science and technology for innovative programs in science;
(2) Science and technology with direct, significant social implications; and,
(3) Directly relates to innovation and the Commonwealth's Backing Australia's Ability initiatives.
That
Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it (WA Curriculum Framework, p. 18)
is one of the Overarching learning outcomes' of the WA Curriculum Framework. Among the specific science learning outcome is
Students select and apply scientific knowledge, skills and understandings across a range of contexts in daily life (WA Curriculum Framework, p. 220).
These and other learning outcomes can be seen as contributing to a 'science for citizenship' approach in which students are prepared for a future as active citizens in a scientific and technological world.
How can the science curriculum best prepare students for such a future? Clearly, one way is to help them understand and develop informed views about modern science and technology issues.
What are some views about biotechnology?
After they have had an opportunity to discuss their own views, teachers might like to consider the views of others. A sample of such views follows.
* Biotechnology is the branch of science that involves genetic manipulation, but in the scientific sense, it is more than just this. The term 'biotechnology' was coined in 1919 by Karl Ereky, a Hungarian engineer, and at the time meant, all the lines of work by which products are produced from raw materials with the aid of living organisms (www.public.asu.edu/~langland/biotech-intro.html).
* Biotechnology includes those biologically based technologies which humans use to yield products of various kinds (Australian Biotechnology Association, 1995). Thus 'biotechnology' includes:
* technologies involving bread and wine-making which have been used for thousands of years;
* cell biology applications such as tissue culture and cloning; and
* genetic engineering.
* Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services. OECD, 1982: http://home.zhwin.ch/~snl/ScriptsTeaching/DefinitionsOfBiotechnology.html
* A broad term originally used to describe the application of biology in the creation of helpful products. (Biotechnology Australia: www.biotechnology.gov.au/)

* Biotechnology means the application of science and engineering in the direct or indirect use of living organisms or parts or products of living organisms in their natural or modified forms - Canadian Environmental Protection Act, 1985: www.oecdobserver.org/news/fullstory.php/aid/81/Some_definitions.html

Finally, it might be worth remembering that not all biotechnologists necessarily subscribe to the view that 'modern' biotechnology is an extension of 'ancient' biotechnology. For example, Martineau (2001, pp. 231-2), wrote:

Nearly every scientist, industrial representative, or U.A. federal regulator who has defended the use of biotechnology in agriculture, for example, has started with the notion that genetic engineering is an extension of traditional breeding. But, despite the fact that this idea has long been the consensus among scientists, at least among those practicing genetic engineering, it is not an established scientific fact. It is opinion. Granted, it is an opinion that many people, especially molecular biologists, might share ... since many anti-biotech Americans have indicated that they do not share that opinion, I question the value of clinging to the "extension of traditional breeding" mantra for either the purpose of defending this new technology or as a cornerstone of "science-based" U.S. regulatory policy.

Box 1: WHAT IS YOUR UNDERSTANDING OF BIOTECHNOLOGY?

From the following list, indicate the items that you think are included in biotechnology.

	Yes	No	Don't Know
1. bread making			
2. IVF procedures			
3. screening for genetic diseases			
4. producing synthetic growth hormones			
5. producing new drought resistant plants by cross-breeding			
6. kidney transplantation			
7. blood typing for transfusions			
8. developing vaccines for new influenza viruses			
9. brewing and wine making			
10. building of an artificial heart			
11. DNA identification of human remains			
12. tissue culture producing skin for grafts			
13. cloning			
14. use of X-rays for medical diagnosis			
15. experimenting the see the effects of tobacco on mice			
16. collecting information on numbers of cancer patients in WA			
17. transferring a gene from one organism to another			
18. producing family trees showing inheritance patterns of a gene			
19. producing new drugs to treat the common cold			
20. using transgenic organisms to produce human hormones			
21. development of new machines for breast cancer screening			
22. use of surveys to find links between lifestyle and Alzheimer's disease			
23. immunisation of children against measles.			

She was a biotechnologist who worked for Calgene, the company that developed the 'first fruit', the Flavr Savr genetically engineered tomato.

FUTURE TECHNOLOGICAL CITIZENS

A small proportion only of our students will be future scientists or technologists. All of them will be citizens. The science education community must do its best to prepare these future technological citizens. Helping our students understand what biotechnology is, and the contested meanings it has, is one important step in the preparation of these future technological citizens. It is difficult to imagine a science/technology with potentially more profound impact on us all. Indeed, biotechnology has the potential to change the very nature of humanity.

Sidebar

A MODEL FOR A SCIENCE DEPARTMENT DISCUSSION

To help students, teachers need to clarify their own understandings, including understanding biotechnology, a 'cutting edge' science and technology. We now offer some suggestions for possible Science Department discussion on what biotechnology is.

1. What do you think of when the term biotechnology is mentioned?
2. Were you feelings towards biotechnology in this context good or bad? Give a reason for feeling like this.
3. List five situations where you believe biotechnology has been used.
4. Which of these situations do you think are advantageous to humans? Give an explanation.
5. Which of these five situations do you believe are unethical? Why do you think so?
6. Complete Box 1 and discuss the differences between lists in view of the four categories of understanding mentioned in the article.
7. If biotechnology were used to produce a transgenic cow that produced milk containing a factor that prevented a common childhood disease, would you support its development? Explain your answer.
8. Select two items from the local newspaper that give differing views of the use of biotechnology to start a discussion on teacher understanding of the concepts and issues arising from the application of biotechnology. An example of this approach could be the benefits of using GM pesticide resistant canola in terms of reducing the amount of pesticides used and the problems caused by canola that has escaped from the cultivated farms lands into neighbouring environments where it has become a weed of pest proportions.

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